§12. Ion Internal Transport Barrier in CHS

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It is interesting phenomena that the location of electron internal transport barrier (ITB) is different from that of ion ITB. In CHS (R = 0.9 – 1.0m and a = 0.2m) the electron ITB typically located near the plasma center at ρ = 0.3, while the ion ITB locates outside of electron ITB, where the ratio of electron temperature to ion temperature is low enough not to degrade ion transport.

In order to investigate the mechanism of ion internal transport barrier, the modulation charge exchange spectroscopy (MCXS), where the observation pointed is scanned with 20mm with a frequency up to 100Hz, has been developed to study the location of maximum ion temperature gradient. The modulation charge exchange spectroscopy consists of object lens mounted on the stage with piezo elements, optical fiber, Fabry-Perot spectrometer, fast 256 channel photo diode detector (PDA) with image intensifier (I.I.). Ion temperature gradient can be derived every 5 ms (half of the modulation period) by taking the slope of ion temperature to the displacement of observation points. The error bar of the ion temperature gradient is estimated by the scatter of ion temperature.

Figure 1 shows the radial profile of ion temperature gradient in the discharge with NBI (t = 40 – 140ms) and ECH (60 - 100 ms) at low density (0.2-0.3 x $10^{19}m^{-3}$). Just after the ECH is turned on the ion ITB appears at t = 66ms. When there is no ion ITB the ion temperature gradient is order of 1-2 keV/m (central ion temperature is 0.2 – 0.3 keV). The ion temperature gradient increases 10 – 15keV/m at the ion ITB region. The region with a large ion temperature gradient is localized at ρ = 0.66 within Δρ = 0.1. Associated with the gradual increase of electron density, the ion ITB region becomes expands and becomes weaker at t = 70ms and finally disappears at t = 100ms..

Figure 2(a) shows the time evolution of ion temperature gradient for the discharge with the magnetic axis of 94.9cm. The ion temperature gradient at ρ = 0.66 increases up to 10 keV/m after the ECH pulse is tuned, while the ion temperature gradient outside ITB (ρ = 0.48 and ρ = 0.78) stays low values (<3keV/m). How long the ITB can be sustained depends on the period in which the electron density can be sustained below the critical value. The ITB is sustained longer in the discharge with the magnetic axis of 97.4cm, where the increase of density after the ECH pulse is slower as shown in Fig.2(b). It should be noted that there are two ITBs observed at ρ = 0.52 and ρ = 0.74, while the ion temperature gradient between two ITBs stays low value (<2keV/m). It is open to question why the outside ITB (ρ = 0.74) appears first and the inner ITB (ρ = 0.52) appears later.

This observation clearly shows that the location of ion ITBs (ρ=0.66 for R_{ax} =94.9cm and ρ = 0.52 and ρ = 0.74 for R_{ax} = 97.4cm) is always outside the electron ITB (ρ=0.3), where the electron temperature is low (<0.5keV) and the ratio of electron temperature to ion temperature is relatively small (<2).

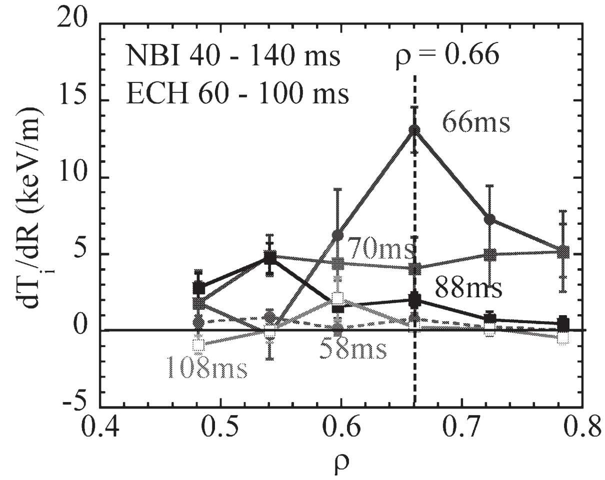
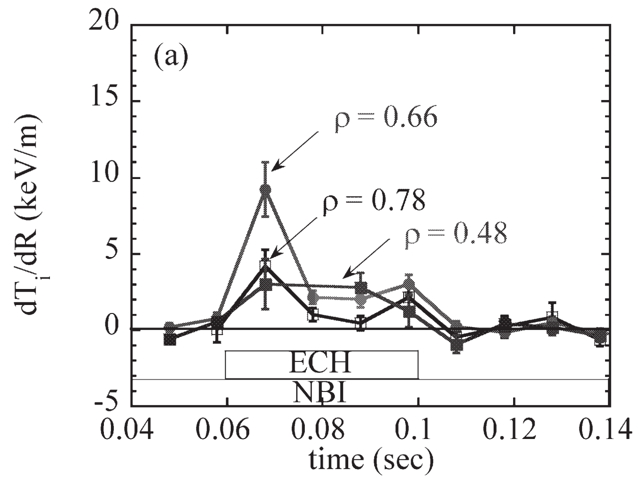


Fig.1 Radial profile of ion temperature gradient measured with MCXS for the plasma with the magnetic axis of 94.9cm



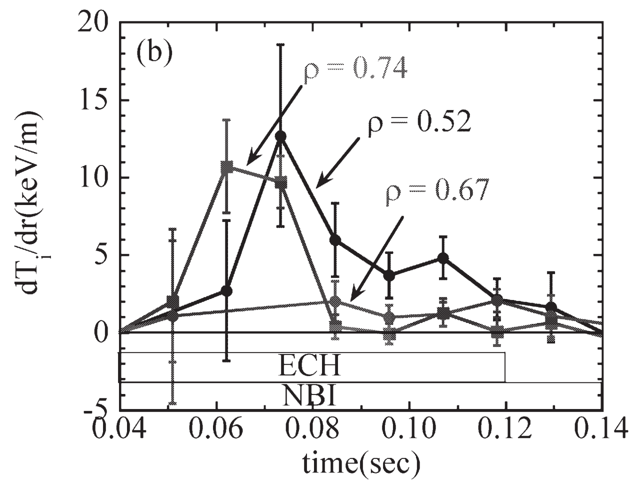


Fig.2. Time evolution of ion temperature gradient measured with MCXS for the plasma with the magnetic axis of (a) 94.9cm and (b) 97.4cm.